Trade-offs in strategies for climate-smart forestry in Europe

Konstantin Gregor\textsuperscript{1}, Thomas Knoke\textsuperscript{1}, Andreas Krause\textsuperscript{1}, Christopher Reyer\textsuperscript{2}, Mats Lindeskog\textsuperscript{3}, Phillip Papastefanou\textsuperscript{1,3}, Anne-Sofie Lansø\textsuperscript{4,5}, Benjamin Smith\textsuperscript{3,6}, and Anja Rammig\textsuperscript{1}

\textsuperscript{1}Technische Universität München, TUM School of Life Sciences, Freising, Germany (konstantin.gregor@tum.de)
\textsuperscript{2}Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Potsdam, Germany
\textsuperscript{3}Department of Physical Geography and Ecosystem Science, Lund University, Lund, Sweden
\textsuperscript{4}Laboratoire des Sciences du Climat et de l’Environnement (LSCE/IPSL) CEA-CNRS-UVSQ, Université Paris-Saclay, Gif-sur-Yvette, France
\textsuperscript{5}Department of Environmental Science, Aarhus University, Denmark
\textsuperscript{6}Hawkesbury Institute for the Environment, Western Sydney University, Penrith NSW, Australia

Forests are a major component of climate change mitigation strategies. However, forests are affected by climate change and measures need to be taken to adapt them to changing conditions. In this context it is also important to consider forests not only as carbon stocks because they provide numerous other important ecosystem services.

“Climate-smart forestry” aims at combining the three aspects of mitigation, adaptation, and continued provision of ecosystem services. Finding concrete strategies for climate-smart forestry is complicated since future climate projections have large uncertainties. Here, we combine dynamic vegetation modeling with robust multi-criteria optimization to assess potentials and issues when trying to make European forest management “climate-smart”.

We applied the dynamic vegetation model LPJ-GUESS and simulated multiple simplified forest management options for a range of climate change scenarios defined by four representative concentration pathways (RCPs). We then defined indicators to measure the performance of various ecosystem services such as global climate change mitigation, local climate regulation through biogeophysical effects, timber provision, and biodiversity. Finally, we used robust multi-criteria optimization to compute forest management portfolios that ensure continued provision of these ecosystem services for all RCPs.

Our optimized portfolios contain large fractions (between 20 and 30\%) of unmanaged forest because of its benefits for biodiversity and local climate regulation. Concerning mitigation, unmanaged forests play a divided role, depending on the assumptions about future use of wood products and the carbon-intensity of non-wood products that could be substituted, e.g. concrete. In addition, a higher share of broadleaved species is proposed throughout Europe, whereas coppice was only found to be beneficial in certain regions, typically regions where it is not a major forest type currently.

Overall, we found that climate-smart forestry cannot eliminate all trade-offs: An implementation of
the portfolios would lead to strong decreases in harvests which lowers the important mitigation potential of wood products. Furthermore we argue that the decrease in harvests could lead to increases in wood imports of possibly unsustainable sources. We thus conclude that while our method offers important insights for forest management strategies, careful considerations need to be made to constrain its application. Namely, concrete prioritization of some ecosystem services will likely be necessary.